



Integrated design and control of wind turbines

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Integrated design and control of wind turbines

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November 2nd, 2010

- Wind Energy Systems
 - Poul Sørensen (main supervisor)
 - Nicolaos Cutululis
 - Anca Hansen
- Aeroelastic Design
 - Peter Bjørn Andersen
 - Lars Christian Henriksen
 - Helen Markou

- 1 Introduction
 - Motivation
 - Objective
 - State-of-the-art

- 2 Frequency support
 - Model description
 - Simulation results

- 3 Summary

Introduction

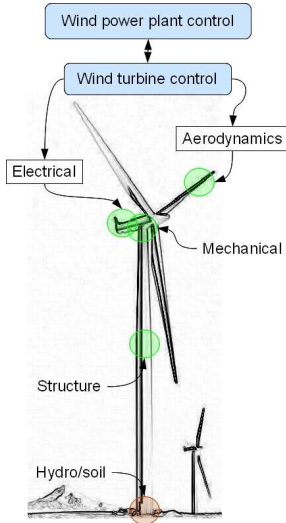


Illustration of wind turbine subsystems

Motivation

Wind turbines under **operating conditions** such as:

- frequency control,
- voltage dips, or
- storm fronts

may observe significant loads.

In this context, the **dynamic interactions** amongst the different subsystems of a wind turbine may prove to be relevant. The focus of this work is on

- aerodynamic,
- structural,
- mechanical,
- electrical and
- control

subsystems of wind turbines.

Introduction

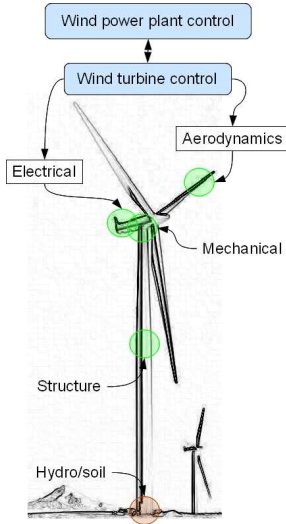


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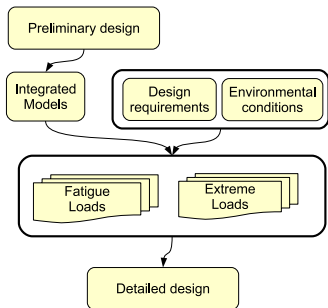


Figure: Basic description of wind turbine design process

Objective

The **general objective** is to develop a framework for the analysis of wind turbines taking into consideration operating conditions relevant for the safe operation of the power system.

Three **milestones** of the project are:

- 1 Implement a simulation platform (HAWC2, Matlab/Simulink).
- 2 Define study cases (models and control).
- 3 Estimate impact on wind turbine loads.

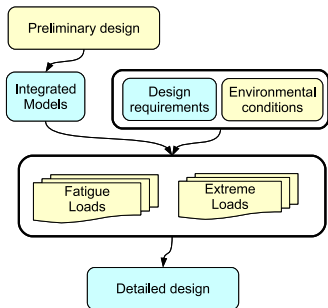


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Introduction

State-of-the-art

Software used for wind turbine simulation:

- Multi-domain modeling
 - MapleSim (Maple)
 - Modelica (Open source)
- Modal software
 - FAST (NREL)
 - Flex5 (DTU)
 - Bladed (Garrad Hassan)
- MBD/FEM software
 - S4WT (SAMTECH)
 - SimPack
 - **HAWC2** (Risø)

... this list is not exhaustive.

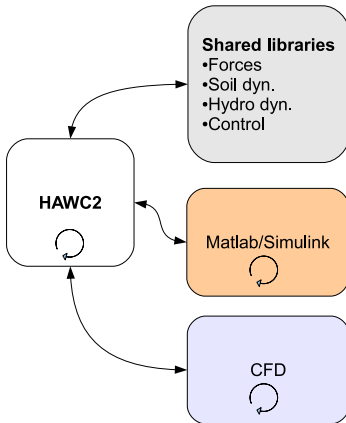


Figure: HAWC2 external interfaces

Introduction

HAWC2 - Matlab link

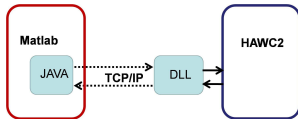


Figure: Description of HAWC2-Matlab link

- Keep both applications stand-alone.
- Make use of built-in interfacing capabilities in Matlab.
- Applications run simultaneously and interact every time step.

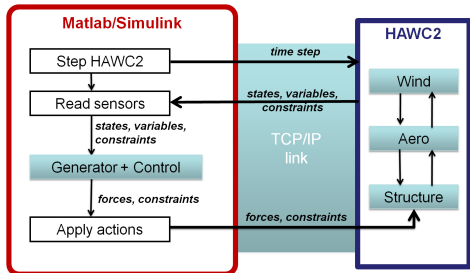


Figure: Integrated Simulation Flow chart

Frequency support

Model description

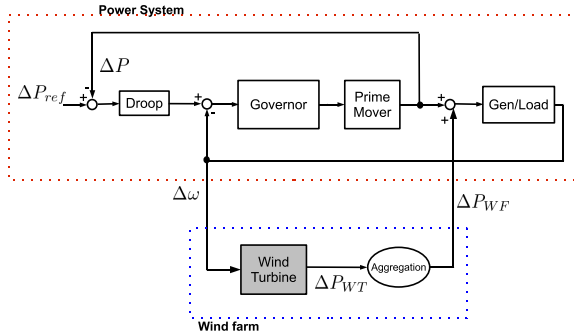


Figure: Description of power system model

Wind turbine inertia emulation at rated wind speed.

Simulation of wind turbine inertia emulation in case of loss of load

- Total capacity of the power system is 60 MW.
- A 12 MW wind farm (DFIG wind turbines) is
 - 1 producing rated power (12 m/s), or
 - 2 disconnected (no WT)
- Inertia Emulation control law
$$\Delta P = 2H_{wt}\omega \frac{d\omega}{dt}$$
- A 8% loss of generation is simulated.

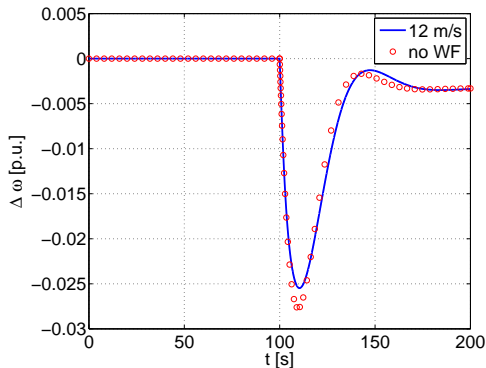


Figure: Power system response to loss of generation

Wind turbine inertia emulation at rated wind speed.

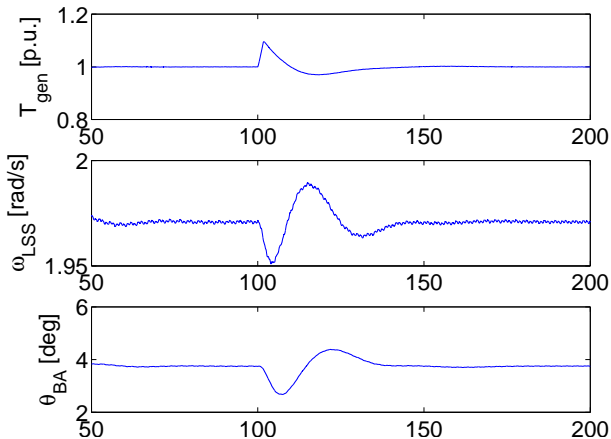


Figure: Wind turbine inertia emulation. From top to bottom: Generator Torque, Low-speed Shaft speed, and Blade angle

Frequency support

Wind turbine inertia emulation at rated wind speed.

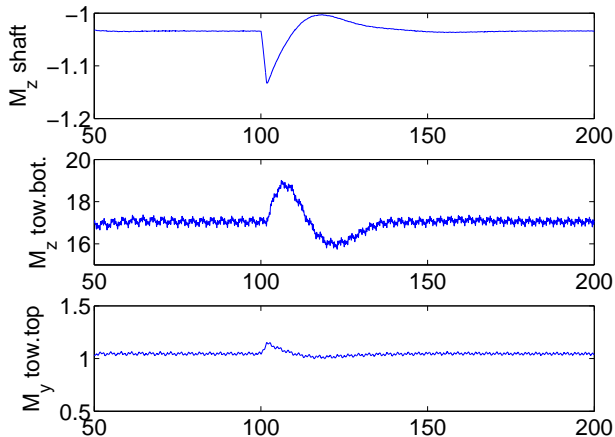


Figure: Wind turbine loads while emulating inertia. From top to bottom: Low-speed shaft moment, Tilting moment at tower bottom, and Yaw moment at tower top (all in MNm).

- HAWC2-Matlab/Simulink is a research tool to analyze the overall dynamics of different subsystems of wind turbines.
- Some mechanical loads on the wind turbine are qualitatively affected by emulating inertia
 - 1 Shaft torque,
 - 2 tilt moment at the tower bottom, and
 - 3 yaw moment at the tower top.
- Quantification of such impact on life-time would show the importance of such loading situations in the overall design of wind turbines.